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# Revision on Shallow-Water Species of the Genus *Placiphorella* (Polyplacophora: Mopaliidae) from Japan

by

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*Abstract.* Three species of the chiton genus *Placiphorella* are recognized in the intertidal and sublittoral zones of Japan: *P. borealis* Pilsbry, 1893, recorded for the first time from Japan proper; *P. stimpsoni* (Gould, 1859) (=*P. japonica* (Dall, 1925)); and *P.* ***borealijaponica*** sp. nov., examples of which have been confused previously with *P. stimpsoni*. The shells, radula, girdle elements, and digestive tract of each species are described and illustrated.

## INTRODUCTION

The so-called veiled chitons, of the Polyplacophoran genus *Placiphorella* (Carpenter MS) Dall, 1879, are peculiar in having depressed and wide valves, anteriorly expanded girdle with scaled bristles, and fingerlike projections of the pallial fold. One of the species, *P. velata* (Carpenter MS) Dall, 1879, was observed to be carnivorous with a peculiar trapping behavior (McLean, 1962). However, the biology of most of the species has never been worked out.

Nine species have hitherto been known from the Pacific Ocean and one from the Atlantic Ocean. In the Pacific Ocean, except for *Placiphorella blainvillii* (Broderip, 1832), eight species among nine are distributed in the North Pacific. From Japan and its adjacent waters, five species have been described, and three species among them—*P. stimpsoni* (Gould, 1859), *P. borealis* Pilsbry, 1893, and *P. japonica* (Dall, 1925)—are regarded as shallow-water dwellers, while the other two—*P. uschakovi* Yakovelva, 1952, and *P. albitestae* Is. Taki, 1954—are deep-water members that are not treated in this paper.

Since their original description, several subsequent authors, including Plate (1901), Berry (1917), Taki (1938, 1954), Leloup (1942), Yakovleva (1952), and Wu & Okutani (1985), have redescribed them. However, no work based on direct comparison of large numbers of specimens has been done.

The present paper describes the morphological characters of each species and clarifies nomenclatural confusion by a critical examination of type materials of these three species and over 100 specimens collected from various localities in Japan.

## MATERIALS AND METHODS

The numbers of specimens examined by species, locality, size, and source are given in Tables 1–4.

Most of the specimens collected by us were fixed in 10% formalin when collected and preserved in 40% isopropyl alcohol.

Observations were made with a stereoscopic dissection microscope and photomicroscope. A scanning electron microscope was used to observe the microstructure of girdle elements and radulae.

Slide calipers were used to measure animal bodies and valves. Girdle elements and radulae were measured with the aid of an eyepiece micrometer.

Drawings were executed with the aid of an eyepiece micrometer and/or camera lucida.

Observed spicules of the perinotum, margin, and hyponotum of most specimens were removed from the middle portion of the body. In observing radulae, the tenth to twentieth transverse rows from the anterior were selected.

The terminology in this paper mostly follows Taki (1938), especially for radular features, and Kaas & Van Belle (1985). However, a few specified terminology used in this paper are as follows:

*Pectinate* or *pectination:* The basic morphology implied by the word pectination (or being pectinate) is not essentially different from how it is used for other chitons. However, pectinations in *Placiphorella* are quite different from those in the family Chitonidae, in which they are finer, deeper, and more numerous than those of *Placiphorella.*

*Prop plate:* A small process of the central tooth, extending anteriorly and supporting this tooth. Terms referring to

Table 1

Data of specimens of *Placiphorella borealis* used in this study.

| Locality | Number of individuals | VL (mm) | Date collected | Source |
|---|---|---|---|---|
| Bering Sea | | | | |
| Bering Island | 1 | — | — | USNM 106922 (holotype) |
| Pacific Coast (all SE Hokkaido) | | | | |
| Nosappu | 7 | 16.6–34.8 | 12 June 1987 | S. Murakamki |
| Kiritappu | 2 | 24.7, 27.1 | 11 June 1987 | S. Murakamki |
| Akkeshi | 1 | 20.9 | 7–8 July 1987 | Y. Kuwahara |
| Akkeshi | 2 | 12.5, 14.9 | 10 July 1982 | Y. Kuwahara |
| Akkeshi | 4 | 9.4–16.8 | 9 July 1983 | Y. Kuwahara |
| Akkeshi | 2 | 18.1, 19.6 | 13 July 1983 | Y. Kuwahara |
| Erimo | 6 | 14.4–23.0 | 14 June 1987 | S. Murakami |

VL, valve length.

the direction of the radular parts are used to indicate the state of withdrawal of the radular ribbon. Thus, for example, the cusp of the major lateral is directed "posteriorly."

*Valve length:* The distance from the anterior tip of the head valve to the posterior tip of the tail valve.

The abbreviations used in this paper for institutions and museums are as follows:

CASIZ—California Academy of Sciences, Department of Invertebrate Zoology, San Francisco.
NSMT—National Science Museum, Tokyo.
USNM—United States National Museum of Natural History, Smithsonian Institution, Washington, D.C.

## Family Mopaliidae Dall, 1889

## Genus *Placiphorella* (Carpenter MS) Dall, 1879

Type species: *Placiphorella velata* (Carpenter MS) Dall, 1879 by O.D.

### *Placiphorella borealis* Pilsbry, 1893

(Figures 1–10, 47, 48)

*Placiphorella stimpsoni:* Dall, 1886:210 (in part, *non* Gould, 1859).
*Placiphorella borealis* Pilsbry, 1893:309–310, pl. 66, figs. 14–17; Yakovleva, 1952:75–76, fig. 35, pl. 5, fig. 3.

**Materials examined:** See Table 1.

Table 2

Data of specimens of *Placiphorella* ***borealijaponica*** Saito & Okutani, sp. nov. used in this study.

| Locality (all Hokkaido) | Number of individuals | VL (mm) | Date collected | Source |
|---|---|---|---|---|
| Pacific Coast | | | | |
| Akkeshi | 2 | 25.5, 27.5 | 10 July 1983 | Y. Kuwahara |
| Muroran | 2 | 23.4, 24.8 | 5 Sept. 1976 | Y. Kuwahara |
| Muroran | 2 | 24.5, 26.3 | 10 Aug. 1983 | Y. Kuwahara |
| Muroran | 1 | 24.1 | 16 Aug. 1987 | H. Saito |
| Hakodate | 2 | 9.0, 22.5 | 14 June 1978 | Y. Kuwahara |
| Okhotsk Sea | | | | |
| Kitami-Esashi | 4 | 11.2–15.2 | 11 Aug. 1987 | H. Saito |
| Japan Sea | | | | |
| Rebun Island | 1 | 17.5 | 13 Aug. 1987 | H. Saito |
| Hashibetsu | 1 | 21.0 | 14 Aug. 1987 | H. Saito |
| Kemafure | 1 | 25.0 | 17 Aug. 1986 | H. Saito |
| Hamamasu | 4 | 10.0–34.0 | 17 Aug. 1986 | H. Saito |
| Otamoi | 3 | 19.0–29.5 | 16 Aug. 1986 | H. Saito |
| Oshoro | 2 | 26.0, 26.0 | 30 Sept. 1982 | Y. Kuwahara |
| Oshoro | 17 | 9.0–31.8 | 18 Aug. 1987 | H. Saito |

VL, valve length.

Table 3

Data of type series of *Placiphorella* ***borealijaponica*** sp. nov.

| | BL (mm) | BW (mm) | VL (mm) | WIV (mm) | Locality | Date collected |
|---|---|---|---|---|---|---|
| Holotype | 38.0 (curled) | 33.4 | 33.4 | 20.8 | Hamamasu | 17 Aug. 1986 |
| Paratype 1 | 45.6 | 34.4 | 34.0 | 23.3 | Hamamasu | 17 Aug. 1986 |
| Paratype 2 | 37.8 | 29.5 | 30.0 | 22.0 | Oshoro | 18 Aug. 1987 |
| Paratype 3 | 37.7 | 25.9 | 24.1 | 18.5 | Muroran | 16 Aug. 1987 |
| Paratype 4 | 24.2 | 16.6 | 17.5 | 10.3 | Rebun Id. | 13 Aug. 1987 |
| Paratype 5 | 29.3 | 23.0 | 21.8 | 16.0 | Oshoro | 18 Aug. 1987 |
| Paratype 6 | 27.9 | 20.2 | 21.0 | 15.5 | Hashibetsu | 14 Aug. 1987 |
| Paratype 7 | 30.0 | 24.5 | 21.8 | 18.0 | Oshoro | 18 Aug. 1987 |
| Paratype 8 | 22.5 (curled) | 22.3 | 20.5 | 16.8 | Oshoro | 18 Aug. 1987 |

BL, body length; BW, body width; VL, valve length; WIV, width of valve IV.

**Description:** Body oval in outline, valves depressed, subcarinate, side slopes nearly straight; girdle widely extended anteriorly, uniformly brown to dark yellowish brown in color (Figures 1, 47).

Valves: Head valve (Figure 3) thick, crescent-shaped, anterior slope straight to slightly concave, with small roundish notch and slightly raised apex, posterior margin of both sides slightly convex; tegmental surface sculptured with numerous, very low, radiating riblets and concentric growth lines; interior smooth, thickened anteriorly; insertion plates short, thickened at both sides of each slit, and somewhat pectinate; usually 8 slits but up to 11; slit rays appear as white lines.

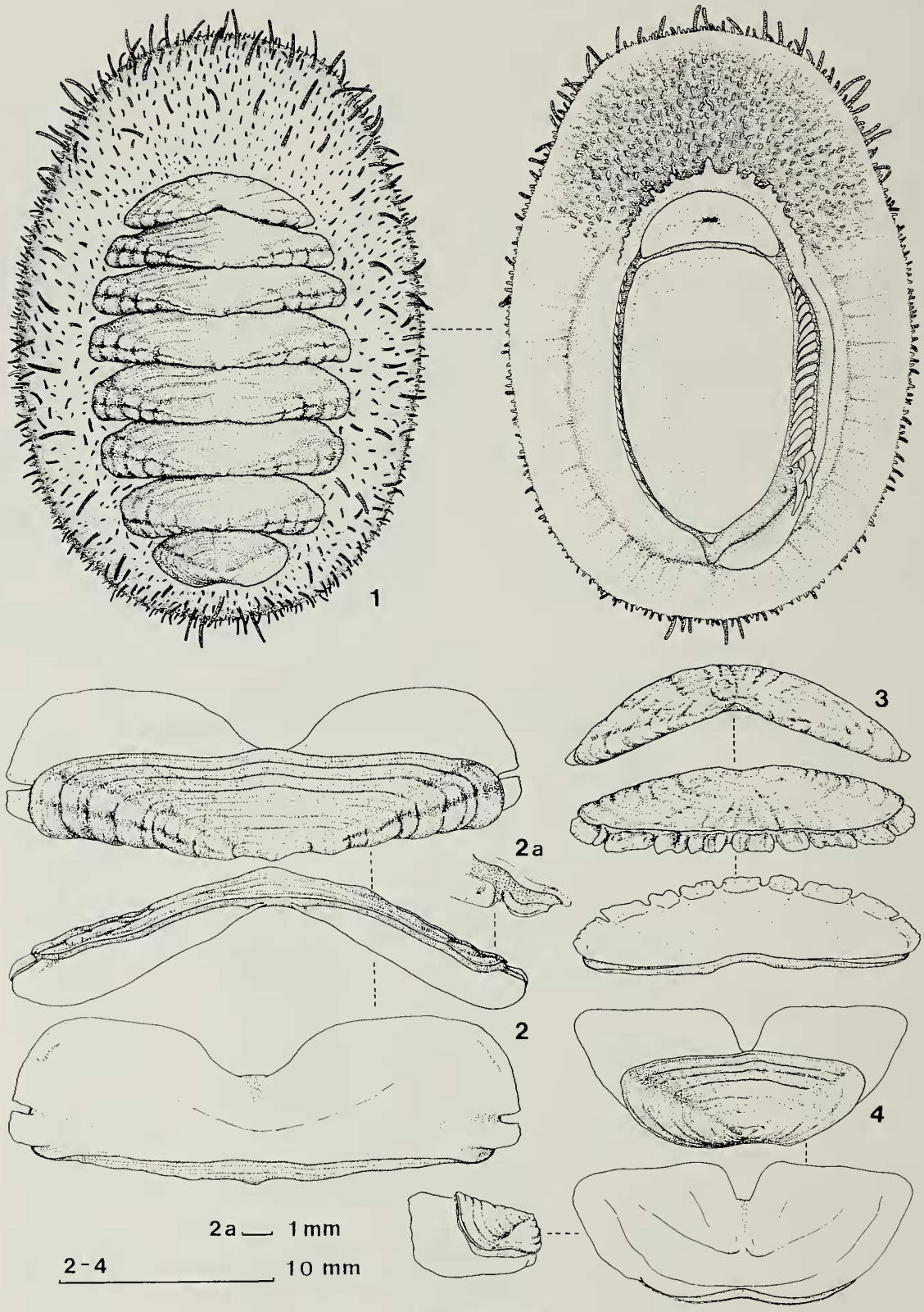
Intermediate valves (Figure 2) oblong in outline, much

Table 4

Data of specimens of *Placiphorella stimpsoni* used in this study.

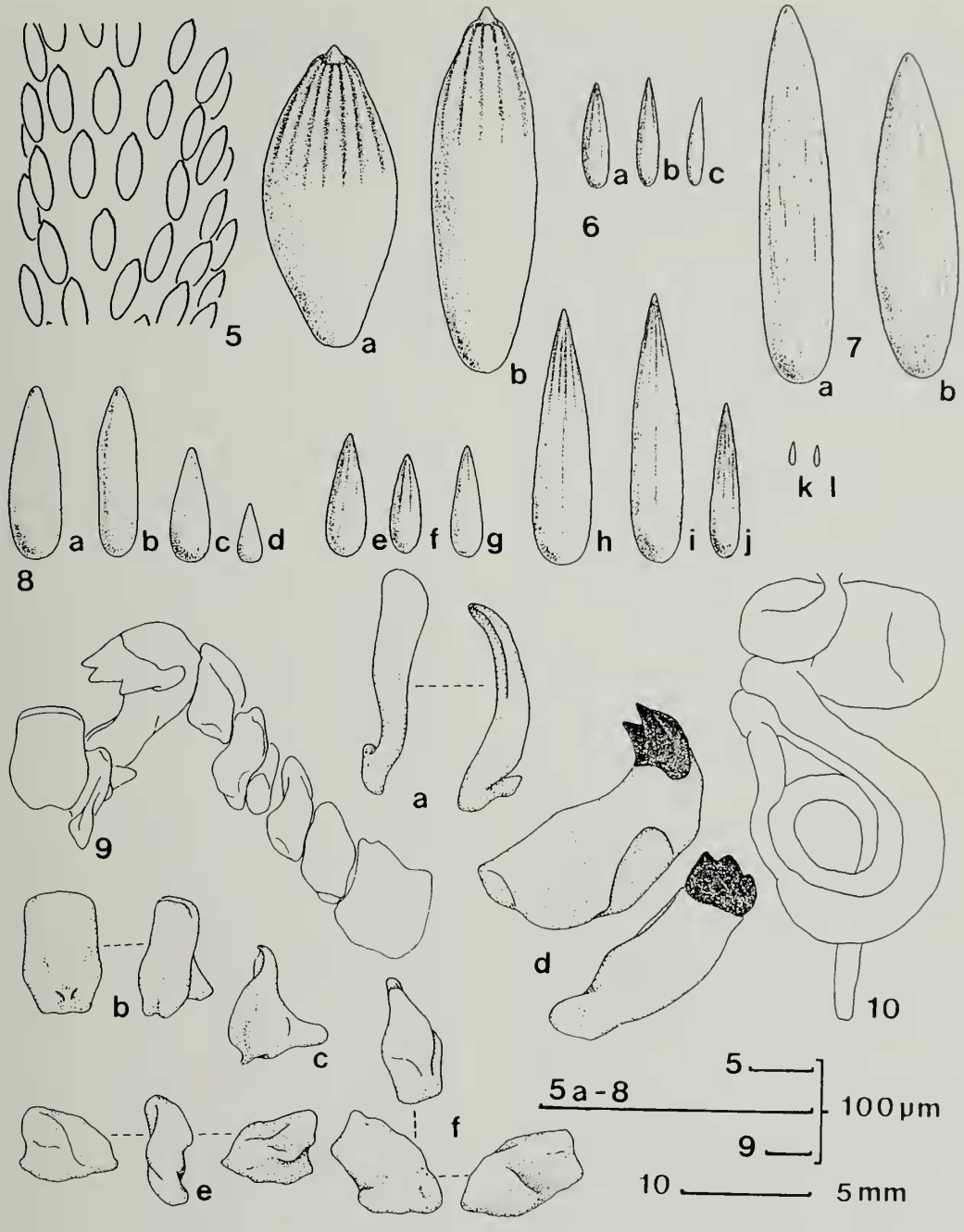
| Locality | Number of individuals | VL (mm) | Date collected | Source |
|---|---|---|---|---|
| Pacific Coast | | | | |
| "Hakodadi" Bay (Hakodate) | 2 | 18.6, 24.5 | — | USNM 1646 (syntypes) |
| "Emi Bashiu" (Emi, Boso Pen.) | 2 | 20.3, 35.0 | — | USNM 333541 (syntypes)* |
| Ozuchi, NE Honshu | 2 | 15.3, 22.3 | 12–19 June 1983 | Y. Kuwahara |
| Ozuchi, NE Honshu | 1 | 18.2 | — | T. Okutani |
| Okirai, NE Honshu | 8 | 12.5–26.2 | 25 June 1987 | S. Murakami |
| Banda, Boso Pen. | 1 | 15.8 | 24 Apr. 1986 | H. Saito |
| Banda, Boso Pen. | 2 | 9.3, 24.8 | 5 June 1986 | H. Saito |
| Banda, Boso Pen. | 1 | 17.8 | 5 Mar. 1987 | H. Saito |
| Manazuru, Sagami Bay | 2 | 26.3–31.8 | 29 Nov. 1987 | H. Saito |
| Shimoda, Izu Pen. | 1 | 33.2 | 7 Aug. 1987 | H. Saito |
| Shimoda, Izu Pen. | 1 | 44.5 | 11 Sept. 1987 | H. Saito |
| Shimoda, Izu Pen. | 4 | 13.9–33.4 | 16–18 May 1988 | H. Saito |
| Sumoto, Inland Sea | 1 | 31.5 | 8 Dec. 1985 | H. Saito |
| Iyo, Inland Sea | 2 | — | — | USNM (no cat. number) |
| Yokonami Pen., Shikoku | 7 | 17.0–28.0 | 3 Nov. 1985 | H. Saito |
| Yokonami Pen., Shikoku | 2 | 12.6, 17.7 | 1 Jan. 1986 | H. Saito |
| Japan Sea | | | | |
| Asamushi, Mutsu Bay | 6 | 19.5–31.6 | 6 Sept. 1986 | S. Murakami |
| Fukuura, N Honshu | 4 | 17.3–21.3 | 21 June 1987 | S. Murakami |
| Fukuoka, Kyushu | 1 | 25.6 | 27 Apr. 1987 | S. Nishihama |
| East China Sea | | | | |
| Amakusa, Kyushu | 1 | 22.5 | 8 Aug. 1987 | S. Nishihama |

VL, valve length; *, *Langfordiella japonica* Dall, 1925.




Explanation of Figures 1 to 4

Figures 1–4. *Placiphorella borealis* Pilsbry, 1893. Valve length 33.8 mm, from Nosappu. Figure 1: dorsal and ventral views of animal. Figure 2: valve IV, dorsal, anterior and ventral views. Figure 2a: valve IV, lateral portion. Figure 3: head valve, dorsal, anterior and ventral views. Figure 4: tail valve, dorsal, ventral and lateral views.




Explanation of Figures 5 to 10

Figures 5–10. *Placiphorella borealis* Pilsbry, 1893. Figures 5–9: valve length 33.8 mm, from Nosappu; Figure 10, valve length 23.0 mm, from Erimo. Figure 5: bristle, arrangement of spicules. Figures 5a, b: spicules of bristle. Figures 6a–c: spicules on perinotum. Figures 7a–c: marginal spicules. Figures 8a–d: spicules on hyponotum. Figures 8e–g: spicules on pallial fold. Figures 8h–j: spicules on fingerlike projection. Figures 8k, l: spicules on papilla. Figure 9: half radula row (major uncinus is removed except for basal plate). Figure 9a: major uncinus, posterior and lateral views. Figure 9b: central, anterior and lateral views. Figure 9c: centro-lateral, lateral view. Figure 9d: major lateral, outer lateral and dorsal views. Figure 9e: outer small lateral, inner lateral, dorsal and outer lateral views. Figure 9f: inner small lateral, dorsal, inner and outer lateral views. Figure 10: digestive tract, dorsal view.

wider than long, valve IV widest, subcarinate, not beaked posteriorly, slightly bending anteriorly in middle of jugal sinus; lateral areas with strong diagonal and sutural ribs, both clearly separated from each other by distinct groove; central area nearly smooth except for concentric growth lines; interior smooth with transverse callus extending from center to near slits and slightly convex anteriorly; slit rays with shallow, fine grooves; sutural laminae very wide, rather thin, gently convex and sharp at anterior edge, separated by wide jugal sinus and usually scarcely connected across jugum; insertion plates thick, short but the longest among species of this genus so far known and extending beyond narrow eaves, hardly pectinate laterally; insertion plates and sutural laminae (Figure 2a) thickened and curved dorsally on sides of slit.

Tail valve (Figure 4) comparatively large for genus, depressed, roughly oval in outline, its greatest width including articulamentum nearly equal to tegmental width of head valve; anterior margin of tegmentum regularly convex and elevated without false beak; mucro distinct, slightly raised, situated near posterior third with convex or straight frontal slope; central area without sculpture except for concentric growth lines; posterior area clearly defined, gradually descending posteriorly; posterior margin shallowly sinuate; interior callused posteriorly; sutural laminae broad, truncated anteriorly, separated by jugal sinus; insertion plates very short, posterior margin slightly pectinate; one slit per side.

Girdle: Perinotum densely covered by minute and slender spicules (Figures 6a–c) with weakly striated distal portion ending in pointed tip, brownish yellow in color, 25–45 $\mu$m in length; bristles on side of sutures (Figure 5) somewhat larger than others; each bristle with smooth surface, composed of small, depressed, ellipsoidal spicules (Figures 5a, b) papillated at tip, deeply striated, brownish, 90–120 $\mu$m in length, arranged in oblique series around axis and not imbricating each other; slightly smaller bristles closely set near anterior margin and posterior to tail valve, sparsely set on rest of perinotum, intermingling with many minute ones; marginal spicules (Figures 7a, b) long, hyaline, smooth, 100–140 $\mu$m in length; hyponotum with numerous small papillae in anterior area; pallial fold much developed, deeply incised at posterior end, extending anteriorly as fingerlike projections; spicules of hyponotum (Figures 8a–d) rather sparse, slightly larger than those of perinotum, hyaline, smooth and blunt at tip, 50–60 $\mu$m in length; spicules on pallial fold (Figures 8e–g) minute, 35–45 $\mu$m in length and sparsely set; spicules on fingerlike projections (Figures 8h–j) slender, hyaline, pointed at tip, finely striated, 55–100 $\mu$m in length; papillae without spicules or, if present, exceedingly minute, shorter than 10 $\mu$m in length and very sparsely set (Figures 8k, l).

Radula (Figure 9): Central tooth (Figure 9b) oblong in outline, slightly dilated at middle of both sides, nearly straight at top with weak but entire cutting edge, basal portion constricted and thickened posteriorly on both sides with shallow concavity narrowing between these thickenings, prop plate with round end; centro-lateral (Figure 9c) with cusped edge at top, posterior portion strongly projecting and reflexed laterally, propped by basal plate with obtuse end; major lateral (Figure 9d) with strongly keeled shaft, dilated ventrally, curving dorsally with tridentate cusp, denticles short, almost equal in size, but middle one slightly larger than lateral ones; inner small lateral (Figure 9e) solid, much elevated, extended anteriorly at bottom; outer small lateral (Figure 9f) also elevated, roughly rhomboid-shaped and sinuate at posterior outer surface; major uncinus (Figure 9a) slender, spoon-shaped, shaft undulate twice with footlike basal plate anteriorly and narrow arched cusp of which length is longer than half length of shaft; inner and middle marginals thick and platelike; outer marginals thin and platelike.

Digestive tract (Figure 10): Stomach large, pouchlike, transversely constricted ventrally, light brown; blind end of stomach extended dorsally to right side of visceral mass, but not reaching dorsal surface; anterior intestine originating from left side of stomach, dorsally running posteriorly with U-shaped loop; intestinal valve directed anteriorly; tract of posterior intestine simple, revolving one and a half times, ventrally leading back to rectum.

Gills, gonopore, and nephridiopore: Gills holobranchial and abanal, originating from under the posterior margin of valve II extending to that of valve VI; gonopore and nephridiopore situated inside of posteriormost gill and behind same respectively.

Heart: Pericardium extending to the boundary between valves V and VI; heart with pair of auricular pores and pair of auriculo-ventricular ostia.

Coloration: Preserved valves whitish along jugum, uniformly dark brown on rest of tegmentum; interior of valves whitish, tinted with light greenish blue; perinotum uniformly light brown to brown; hyponotum light brown except for olivaceous anterior portion, often maculated with red when alive.

**Remarks:** This species was first described by PILSBRY (1893) based on a single specimen from Bering Island. The specimen was one of five specimens identified as *Placiphorella stimpsoni* by DALL (1886). Redescriptions were provided by BERRY (1917) and YAKOVLEVA (1952). Many differences exist between the holotype (USNM 106922) (Figure 48) and specimens identified by BERRY (1917) as *P. borealis* (USNM 215633) collected from a depth of 228 fathoms (ca. 417 m) off Shimshir Island, Kurile Islands. Berry's specimens have whitish valves, a narrower head valve, a smaller tail valve with the mucro situated at the posterior end, and a smooth perinotum. Judging from a comparison of the external morphology with the original description, the paratype of *P. uschakovi* Yakovleva, 1952 (CASIZ 019464) and locality records, Berry's specimens seem to be identical with *P. uschakovi*. The present species also resembles *P. **borealijaponica***, which is described in this paper as a new species (see **Remarks** under *P. **borealijaponica***).

**Distribution:** Bering Sea, Okhotsk Sea, Japan Sea, and Pacific Ocean from Bering Island to east coast of Hokkaido. Found on littoral and sublittoral zones of rocky shore.

*Placiphorella* ***borealijaponica*** Saito & Okutani, sp. nov.

(Figures 11–27, 49)

*Placiphorella stimpsoni:* ?DALL, 1886:210 (in part); PLATE, 1901:300–307, pl. 12, figs. 321–327; Is. TAKI, 1938: 350–355, pl. 14, figs. 13, 17, pl. 21, figs. 3, 7–9, pl. 22, figs. 7–15; 1954:26, pl. 11, figs. 5, 6; YAKOVLEVA, 1952: 76, fig. 36, pl. 5, fig. 4; ISHIKAWA, 1966:96. (All *non Chiton stimpsoni* Gould, 1859).

**Materials examined:** See Table 2.

**Description:** Body oval to broadly oval in outline, valves depressed, subcarinate, side slopes nearly straight; girdle widely extended anteriorly, uniformly olivaceous to light brown (Figures 11, 49).

Valves: Head valve (Figure 13) thick, stout, narrowly crescent-shaped, anterior slope straight to slightly concave with small roundish notch at apex, posterior margin of both sides slightly convex; tegmental surface without any sculpture except for concentric growth lines, but sometimes somewhat rough and wavy; posterior margin hardly raised; interior smooth, strongly thickened anteriorly; insertion plates short, thick, and weakly pectinate; slits usually 8, but occasionally up to 10 in number; slit rays inconspicuous.

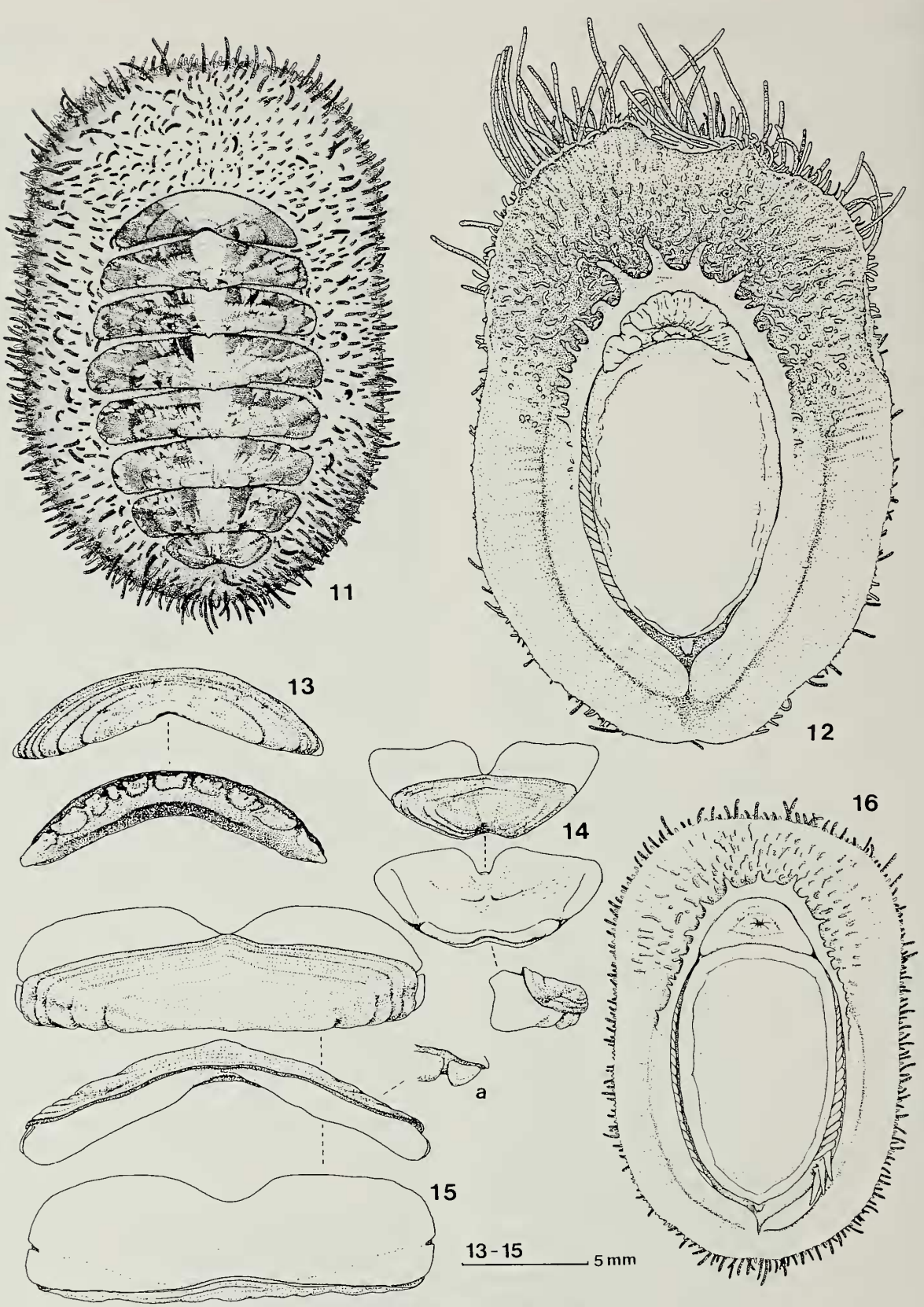
Intermediate valves (Figure 15) oblong in outline, much wider than long, widest at valve IV, subcarinate, not beaked posteriorly, having gently projecting false beak; lateral areas distinctly elevated with obsolete but wide diagonal and sutural ribs, both barely separable by shallow excavation; central area nearly smooth except for concentric growth lines; interior smooth with transverse callus, slightly convex anteriorly, extending from center to near slits; slit rays inconspicuous; sutural laminae very wide, thick, nearly straight and sharp at anterior edge, widely incised by jugal sinus, usually barely connected across jugum; insertion plates thick, short but usually extending beyond narrow eaves, obtuse at edge, slightly pectinate on lateral surface; insertion and sutural plates (Figure 15a) thickened, wedgelike on sides of slit.

Tail valve (Figure 14) small, depressed, roughly rhombic in shape, its greatest width including articulamentum decidedly shorter than tegmental width of head valve, and tegmental width slightly shorter than half width of those of valve IV: anterior margin of tegmentum regularly convex without false beak; mucro slightly raised, situated nearly at posterior end with shallow sinus; central area nearly smooth, slope slightly concave anterior to mucro; diagonal ribs raised, often roughened by growth lines, posterior area narrow; interior of valve callused posteriorly; sutural laminae broad, truncated anteriorly, separated by narrow sinus; insertion plates very short but clearly defined, posterior margin faintly roughened; one slit per side.

Girdle: Perinotum densely covered by minute, slender brownish orange spicules (Figures 18a, b) with deeply striated distal portion ending in a pointed tip, 30–50 μm in length; bristles on side of sutures (Figure 17) somewhat larger than others, smooth, composed of depressed, ellipsoidal, distally papillated, strongly striated, brownish orange spicules (Figure 17a), 100–150 μm in length, arranged in oblique series around axis and not imbricating each other; slightly smaller bristles closely set near anterior margin and posterior to tail valve, sparsely set on rest of perinotum, intermingling with many minute ones; marginal spicules (Figure 19) long, hyaline, nearly smooth, sharply pointed at tip, 130–200 μm in length; hyponotum with numerous small papillae that often coalesce to form a vermicular pattern in anterior region; pallial fold well developed, deeply incised at posterior end, extending anteriorly as fingerlike projections; spicules of hyponotum (Figures 20a–d) densely set, decidedly longer than those of perinotum, smooth, hyaline, blunt at tip, 80–120 μm in length; spicules on pallial fold (Figures 20e–g) slightly longer, attaining 160 μm in length; fingerlike projections also with hyaline spicules (Figures 20h, i), of which shape almost same as those on perinotum; spicules on papillae (Figure 20j) minute, hyaline, finely striated, 20–30 μm in length and sparsely set.

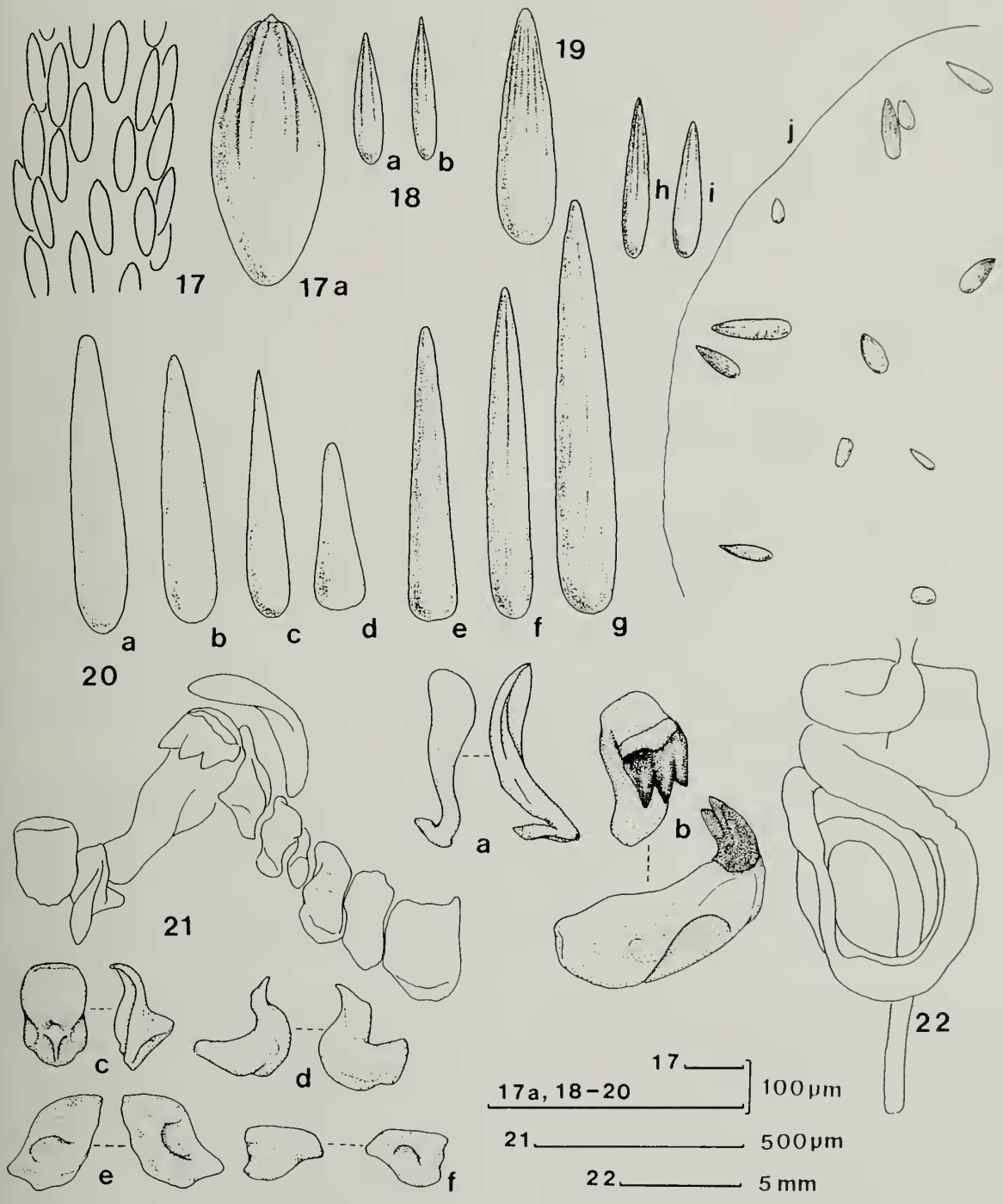
Radula (Figure 21): Central tooth (Figure 21c) oblong in outline, slightly sinuate at the middle on both sides, gently arched at top with entire cutting edge, basal portion abruptly constricted and thickened posteriorly on both sides with a shallow concavity narrowing between these thickenings, small projection sometimes present between these thickenings, then basal part of posterior end becoming trilobed, prop plate thick with round end; centro-lateral (Figure 21d) with dorsal edge ascending to lateral corner which is slightly thickened and reflexed as small cusp, posterior portion thickened, concaved laterally, forming an auricular projection, basal plate truncated laterally; major lateral (Figure 21b) with strongly keeled shaft, dilated ventrally, curving dorsally with tridentate cusp; denticles are nearly equal in size but middle one slightly larger than lateral ones; inner small lateral (Figure 21e) solid, much elevated, bottom wider than top, narrowly elongate anteriorly; outer small lateral (Figure 21f) also elevated, roughly rhomboid-shaped, roundly sinuate at posterior outer surface; major uncinus (Figure 21a) spoon-shaped, shaft undulated twice with footlike basal plate and arched cusp of which length is longer than half length of shaft; inner and middle marginal thick, platelike, often with small pore basally; outer marginal large, thin, platelike.

Digestive tract (Figure 22): Stomach large, pouchlike, transversely constricted ventrally, light grayish brown; blind end of stomach extended dorsally to right side of visceral mass, but not reaching dorsal surface; anterior intestine originating from left side of stomach, running posteriorly with U-shaped loop; intestinal valve directed anteriorly; tract of posterior intestine simple, revolving one and a half times ventrally, leading back to rectum.




Explanation of Figures 11 to 16

Figures 11–16. *Placiphorella* ***borealijaponica*** Saito & Okutani, sp. nov. Figures 11, 16: paratype 4; Figure 12, paratype 3; Figures 13–15, paratype 5. Figure 11: dorsal view of animal. Figure 12: ventral view of animal. Figure 13: head valve, dorsal and ventral views. Figure 14: tail valve, dorsal, ventral, and lateral views. Figure 15: valve IV, dorsal, anterior, and ventral views. Figure 15a: valve IV, lateral portion. Figure 16: ventral view of animal.




Explanation of Figures 17 to 22

Figures 17–22. *Placiphorella* ***borealijaponica*** sp. nov. Figures 17–22: paratype 2; Figure 21, paratype 1. Figure 17: bristle, arrangement of spicules. Figure 17a: spicule of bristle. Figures 18a, b: spicules on perinotum. Figure 19: marginal spicule. Figures 20a–d: spicules on hyponotum. Figures 20e–g: spicules on pallial fold. Figures 20h, i: spicules on fingerlike projection. Figure 20j: spicules on papilla. Figure 21: half radula row (major uncinus is removed except for basal plate and major uncinus of a row immediately anterior is shown). Figure 21a: major uncinus, posterior and inner lateral view. Figure 21b: major lateral, anterior and outer lateral views. Figure 21c: central, anterior and lateral views. Figure 21d: centro-lateral, both lateral views. Figure 21e: inner small lateral, both lateral views. Figure 21f: outer small lateral, both lateral views. Figure 22: digestive tract, dorsal view.

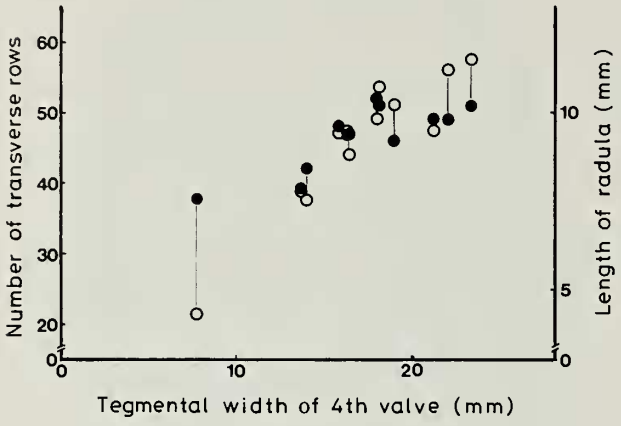



Figure 23

Relationship between width of valve IV and radula. Open circles, length; solid circles, number of transverse rows ($n$ = 12).

Gills, gonopore, and nephridiopore: Gills holobranchial and abanal, originating at posterior margin of valve II to that of valve VI; gonopore and nephridiopore situated between inside of two posteriormost gills and posterior to last gill respectively.

Heart: Pericardium extending to the boundary between valves V and VI; heart with pair of auricular pores and pair of auriculo-ventricular ostia.

Coloration: In preserved condition, valves whitish along jugum, uniformly brown or brown with white and blue streaks on rest of tegmentum; interior of valves light blue, often tinted with brown on insertion plate of head valve; perinotum uniformly olivaceous to light brown; hyponotum light brown.

Ontogenetic variations: No marked changes in morphological characters present in body length from 12 to 47 mm. Transverse rows of radula gradually increase with growth (Figure 23).

**Type locality:** Hamamasu, Hokkaido.

**Type depository:** Holotype in NSMT Mo-64663, paratypes 1 to 4 in NSMT Mo-64664 to Mo-64667, paratypes 5 and 6 in USNM 859353 and 859354, paratypes 7 and 8 in CASIZ 066636 and 066637.

**Remarks:** Owing to similar general appearance, the present species has long been confused with *Placiphorella stimpsoni* (Gould, 1859). The type specimen of *P. stimpsoni* was collected from "Hakodadi Bay" (Hakodate Bay). DALL (1925) established a new genus *Langfordiella* based on his species *L. japonica* collected from "Emi Bashiu" (Emi, Chiba Prefecture). TAKI (1938) ignored the genus *Langfordiella* and considered *L. japonica* to be identical with his *P.* "*stimpsoni*" collected from Mutsu Bay, but later he (1954) separated them into two species.

An examination of the type specimens of *Chiton* (*Molpalia*) *stimpsoni* Gould, 1859 (USNM 1646) (Figure 50)

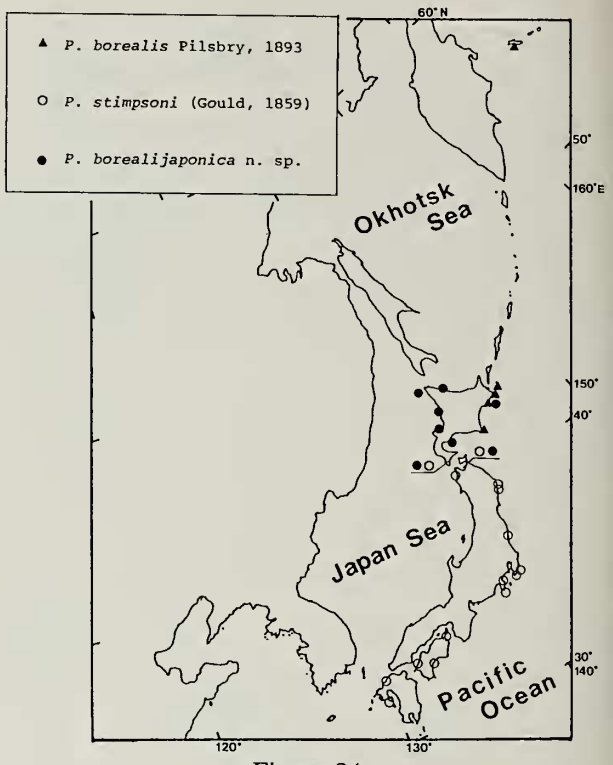



Figure 24

Distribution of the three species of *Placiphorella* examined in this study.

and *Langfordiella japonica* Dall, 1925 (USNM 333541; see Figure 52) as well as 93 specimens collected from various Japanese localities, indicates that *Placiphorella stimpsoni* (Gould, 1859) and *P. japonica* (Dall, 1925) are conspecific, but *P.* "*stimpsoni*" *sensu* TAKI (1938, 1954) is a different species which is here described as a new species. One reason for past confusion may be that *P. stimpsoni* and *P.* ***borealijaponica*** sp. nov. are sympatric around the Tsugaru Strait (Figure 24). South of the southern tip of Hokkaido one finds *P. stimpsoni* while *P.* ***borealijaponica*** occurs to the north of the northern tip of Honshu. Differences between these two species include: the shape of the tail valve, insertion plate of the head valve, spicules of the bristles, and color of the perinotum. Spicules of the bristles of the two species are different not only in shape but also in size (Figure 25). *Placiphorella* ***borealijaponica*** also closely resembles *P. borealis* but is separable by morphological differences of the head and tail valve and spicules on the hyponotum. Ratios of articulamental width of the tail valve to tegmental width of the head valve are considerably different between these two species (Figure 26). Other differences between the three species are summarized in Figure 27.

Some anatomical features of the soft parts of these three species were also compared. Although no distinct feature

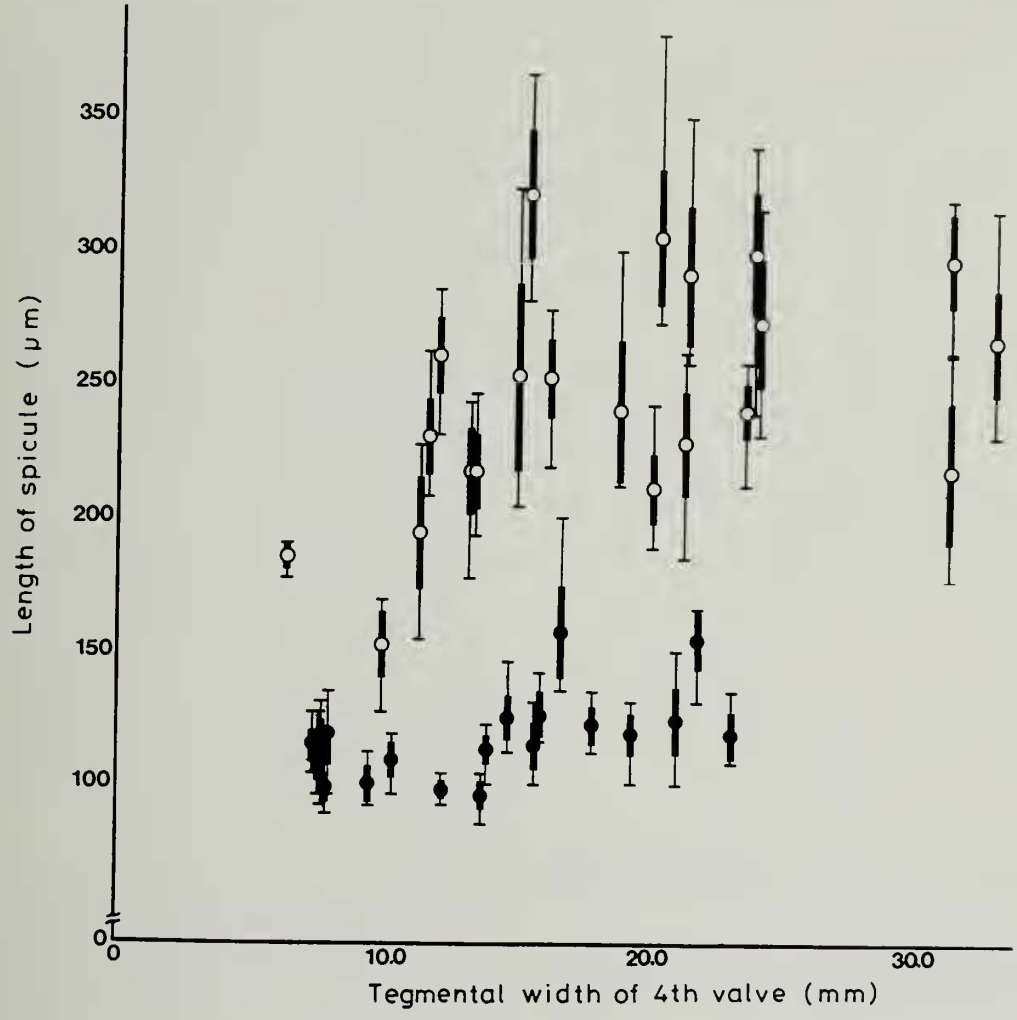



Figure 25

Relationship between tegmental width of valve IV and length of spicule on bristles in two *Placiphorella* species. Vertical solid bars, standard deviation; lines, range. Open circles, mean for *P. stimpsoni*; solid circles, mean for *P. **borealijaponica***.

could be used to distinguish one from another, several facts were noteworthy.

The general looping pattern of the digestive tract is almost the same among all three species; however, it is slightly more complicated in *Placiphorella stimpsoni* than in the others. This pattern is stable even when the gut is pressed by the mature gonad.

The nephridiopore is situated posterior to the posteriormost gill in all three species. According to Pelseneer (1898, *fide* HYMAN, 1967) and PLATE (1901), the nephridiopore of most species that have abanal gills is situated anterior to the posteriormost gill. Plate noted that *Tonicella marmorea*, which has the nephridiopore situated posterior to the posteriormost gill, is the only exception.

The auriculo-ventricular ostia are found in a single pair in all three species. This state is considered to represent a rather primitive condition, because Lepidopleuridae and Ischnochitonidae have only a single pair of auriculo-ventricular ostia besides selected species of the Mopaliidae, namely, *Mopalia muscosa*, *M. wosnessenski*, *Amicula pallasi*, and *Katharina tunicata* (PLATE, 1901).

**Distribution:** Northern part of Honshu and Hokkaido, northwestern part of Pacific Ocean, Okhotsk Sea, northern part of Japan Sea. Found on rocks or under large stones in the littoral and sublittoral zones.

*Placiphorella stimpsoni* (Gould, 1859)

(Figures 28–46, 50–52)

*Chiton* (*Molpalia*) [*sic*] *stimpsoni* GOULD, 1859:165; 1862: 118 (*fide* TAKI, 1938); JOHNSON, 1964:153.

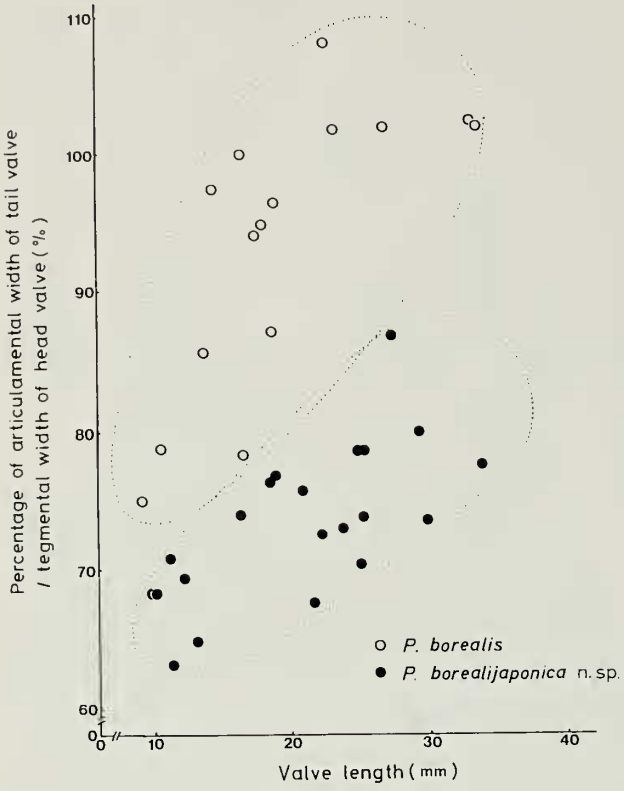



Figure 26

Relationship between valve length and percentage of articulamental width of tail valve divided by tegmental width of head valve of *Placiphorella borealis* and *P. **borealijaponica***.

*Placiphorella stimpsoni:* Pilsbry, 1893:307–309, pl. 62, figs. 84–87; Berry, 1917:12–13, pl. 8, figs. 1, 2, pl. 9, figs. 1–8; Leloup, 1942:13, fig. 5.
*Placiphorella* sp.: Is. Taki, 1924:286–287, 1 text-fig.
*Langfordiella japonica* Dall, 1925:96; Thiele, 1929:11.
*Placiphorella japonica:* Is. Taki, 1954:24–26, pl. 11, figs. 3, 4, pl. 12, figs. 4, 5, pl. 13, figs. 6–9, pl. 14, figs. 5–8, pl. 15, figs. 1, 2, 7; Ishikawa, 1966:96, pl. 1, fig. 10.

**Materials examined:** See Table 4.

**Description:** Body broadly oval in outline; valves depressed, subcarinate, side slopes nearly straight; girdle broadly extended anteriorly, dark bands on light colored background (Figures 28, 51).

Valves: Head valve (Figures 29, 30, 32) thick, stout, wide, crescent-shaped, anterior slope straight to slightly convex, with shallow roundish notch at apex, posterior margin of both sides slightly convex; tegmental surface without any sculpture except for concentric growth lines, posterior margin barely raised; interior smooth, strongly thickened anteriorly; insertion plates short, exceedingly thick and deeply pectinate, occasionally with minute, irregularly arranged accessory denticles anteriorly (Figure 30a); usually 8 slits but occasionally up to 12; slit rays corresponding to slits but not grooved, provided with several minute pores.

Intermediate valves (Figures 31, 35) oblong in outline, much wider than long, widest at valve IV, subcarinate, not beaked posteriorly, having small but usually sharply projecting false beak; lateral areas distinct, elevated, with inconspicuous but wide diagonal and sutural ribs, shallowly excavated in between; central area nearly smooth; interior smooth with transverse callus slightly convex anteriorly, extending from center to near slits; slit rays indistinctly grooved; slit narrow, one on each side; sutural laminae very wide, nearly straight and sharp at anterior edge, shallowly and widely incised by jugal sinus, but usually connected across jugum by narrow lamina; insertion plates thick, short, usually not extending beyond narrow eaves, obtuse at edge, pectinate on outer surface.

Tail valve (Figure 34) small, depressed, roughly widely triangular in outline, its greatest width including articulamentum decidedly shorter than tegmental width of head valve; anterior edge slightly convex, often lacking small false beak; posterior margin bordered by raised diagonal ribs, slightly sinuate at posterior end; posterior area narrow, lying beneath diagonal ribs; central area nearly smooth, slope slightly concave anterior to mucro; interior heavily callused posteriorly; slit poorly developed but sometimes obsolete or lacking in older animals; sutural laminae broad, truncated at anterior edge, narrowly and deeply incised by jugal sinus, but usually connected to each other across jugum.

Girdle: Perinotum beset with minute, hyaline, drop-shaped spicules (Figures 41a–c), 35–55 μm in length, often with bubblelike structure internally; bristles on sutures (Figure 39) large, smooth, composed of long spicules (Figures 39a–d) arranged in oblique series around axis and imbricating each other; spicules striated, papillated at tip, brown or olive green, 200–350 μm in length; slightly smaller bristles closely set near anterior margin and posterior to tail valve; smallest ones closely set around margin, sparsely set on rest of perinotum; marginal spicules (Figures 40a, b) long, hyaline, sharply pointed at tip, distal two-thirds finely striated, 120–140 μm in length; hyponotum with numerous small papillae often coalescing to form a vermiculation in anterior portion, having well developed pallial fold deeply incised at posterior end, extending anteriorly as fingerlike projections; spicules of hyponotum (Figures 42a–c) densely set, decidedly larger than those on perinotum, hyaline, smooth, blunt at tip, 100–135 μm in length; spicules on pallial fold (Figures 42d–g) slightly longer and more slender; papillae sparsely set with small, hyaline, smooth spines (Figure 42j), 30–50 μm in length.

Radula (Figure 43): Central tooth oblong in outline, nearly straight on both sides having strong and entire cutting edge at top, abruptly constricted and thickened posteriorly on both sides of basal portion where concavity narrows, prop plate triangular with simple round end; centro-lateral slightly thickened at lateral corner of top, projecting and thickened posteriorly, curving dorsally

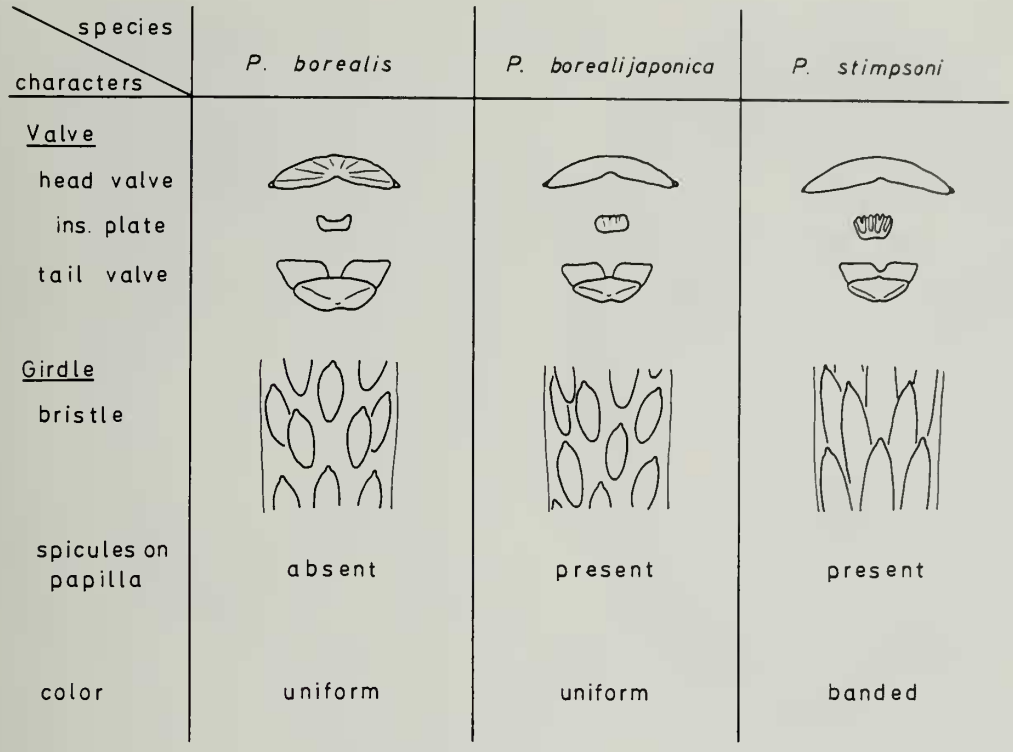



Figure 27

Distinctions among the three species of *Placiphorella*.

forming auriculate projection, basal plate with truncate end; major lateral with strongly keeled shaft, dilated ventrally, curving upward anteriorly with tridentate cusp; denticles nearly equal in size, but middle one slightly longer than others; inner small lateral solid, much elevated posteriorly, bottom wider than top, narrowly elongated anteriorly; outer small lateral also elevated, rhomboid-shaped, sinuate at posterolateral surface; major uncinus slightly curved with narrow cusp of which length is about half length of shaft; inner and middle marginals rhombic

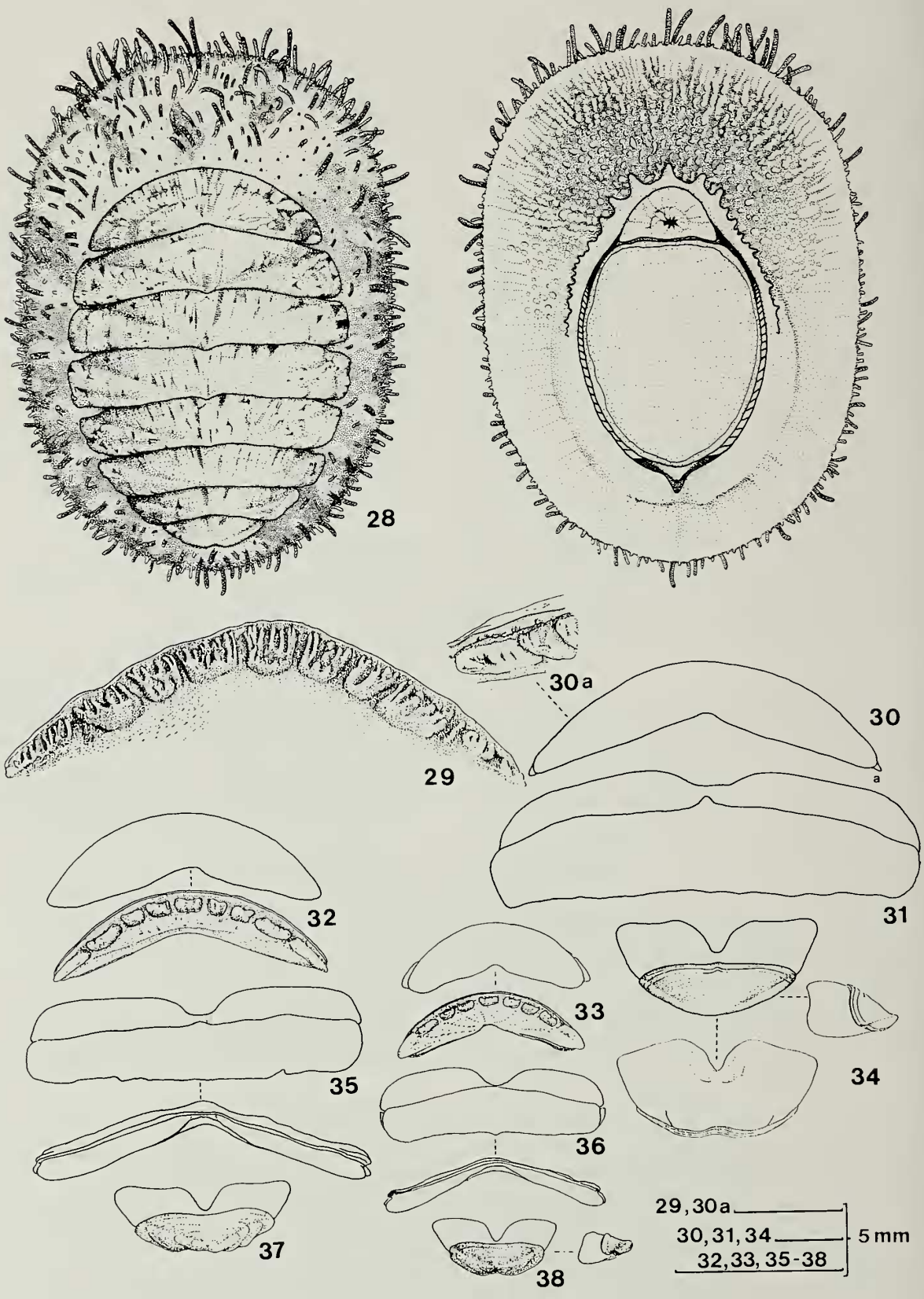
→

## Explanation of Figures 28 to 38

Figures 28–38. *Placiphorella stimpsoni* (Gould, 1859). Figure 28: valve length 31.9 mm, from Manazuru; Figure 29: valve length 35.0 mm, from Emi, USNM 333541 (one of the syntypes of *Langfordiella japonica*); Figures 30, 31, 34: valve length 33.2 mm, from Shimoda; Figures 32, 35, 37: valve length 12.6 mm, from Yokonami Pen.; Figures 33, 36, 38: valve length 9.3 mm, from Banda. Figure 28: dorsal and ventral view of animal. Figure 29: insertion plates of head valve. Figure 30: head valve, outline of dorsal view. Figure 30a: insertion plates and accessory denticles. Figure 31: valve IV, outline of dorsal view. Figure 32: head valve, outline of dorsal view and ventral views. Figure 33: head valve, outline of dorsal view and ventral views. Figure 34: tail valve, dorsal, ventral, and lateral views. Figures 35, 36: valve IV, outline of dorsal and anterior views. Figure 37: tail valve, dorsal view. Figure 38: tail valve, dorsal and lateral views.

## Explanation of Figures 39 to 44

Figures 39–44. *Placiphorella stimpsoni* (Gould, 1859). Figure 39a: valve length 18.2 mm, from Ozuchi; Figure 39b: valve length 31.5 mm, from Sumoto; Figure 39c: valve length 15.3 mm, from Ozuchi; Figure 39d: valve length 12.6 mm, from Yokonami Pen.; Figures 40–42: valve length 31.9 mm, from Manazuru Pen.; Figures 43, 44c: valve length 33.2 mm, from Shimoda; Figure 44a: valve length 9.3 mm, from Banda; Figure 44b: valve length 24.8 mm, from Banda. Figure 39: bristle, arrangement of spicules. Figures 39a–d: spicules of bristle. Figures 40a, b: marginal spicules. Figures 41a–c: spicules on perinotum. Figures 42a–c: spicules on hyponotum. Figures 42d–g: spicules on pallial fold. Figures 42h, i: spicules on fingerlike projection. Figures 42j: spicules on papilla. Figure 43: half radula row (major uncinus is removed except for basal plate and major uncinus of a row immediately anterior is shown). Figures 44a–c: digestive tract, dorsal view.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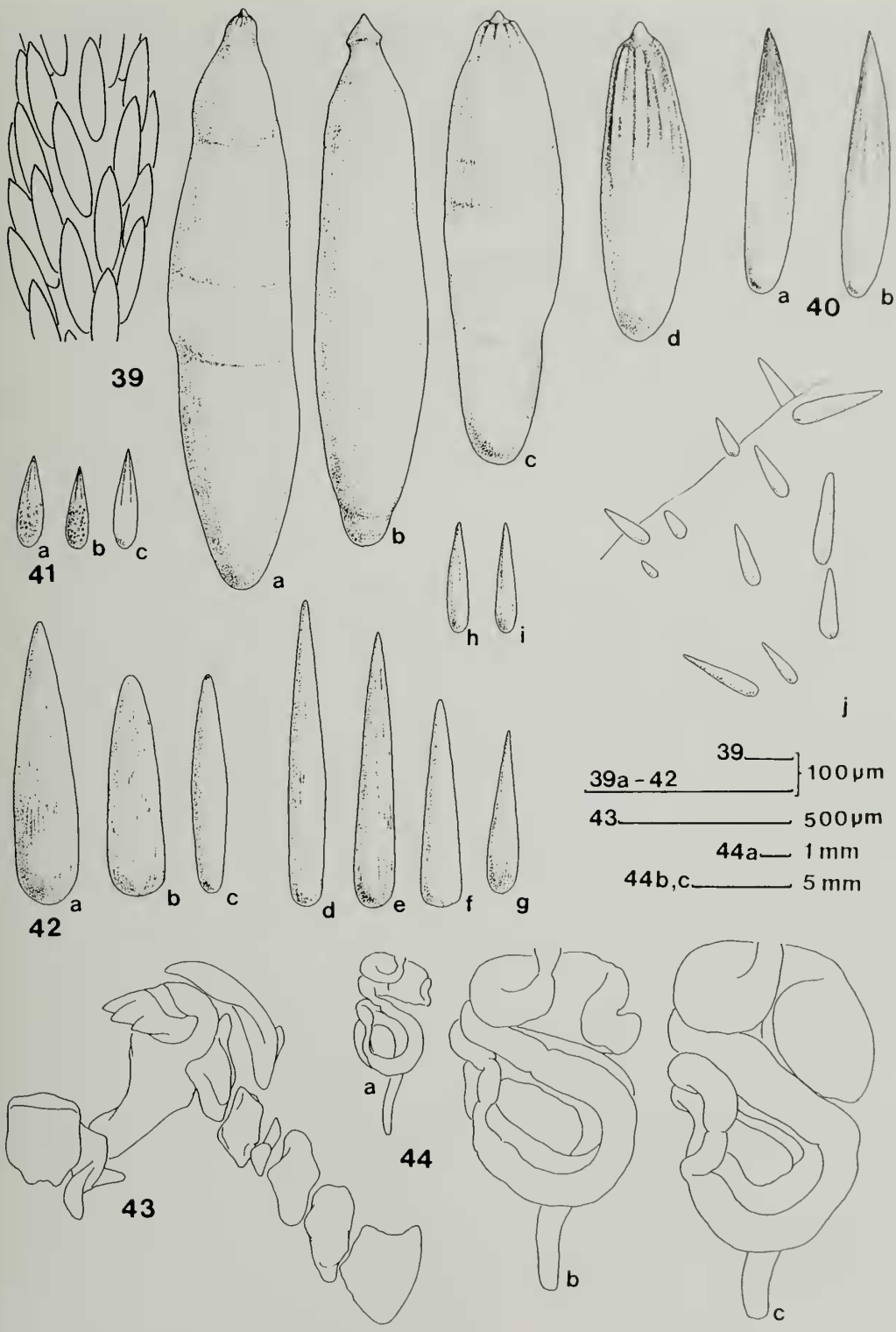
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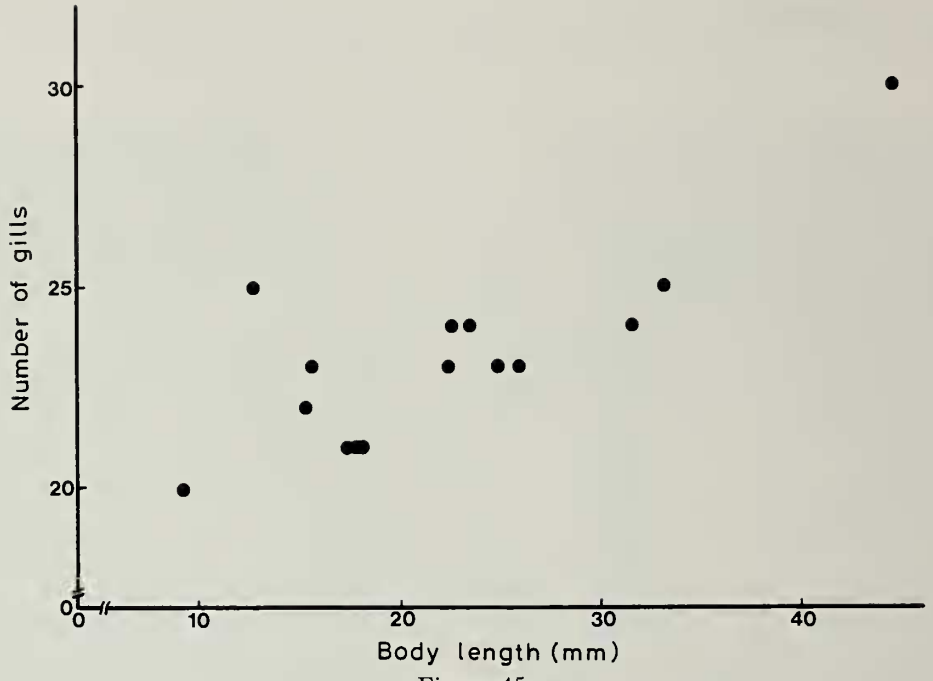


Figure 45

Relationship between body length and number of gills ($n$ = 15).

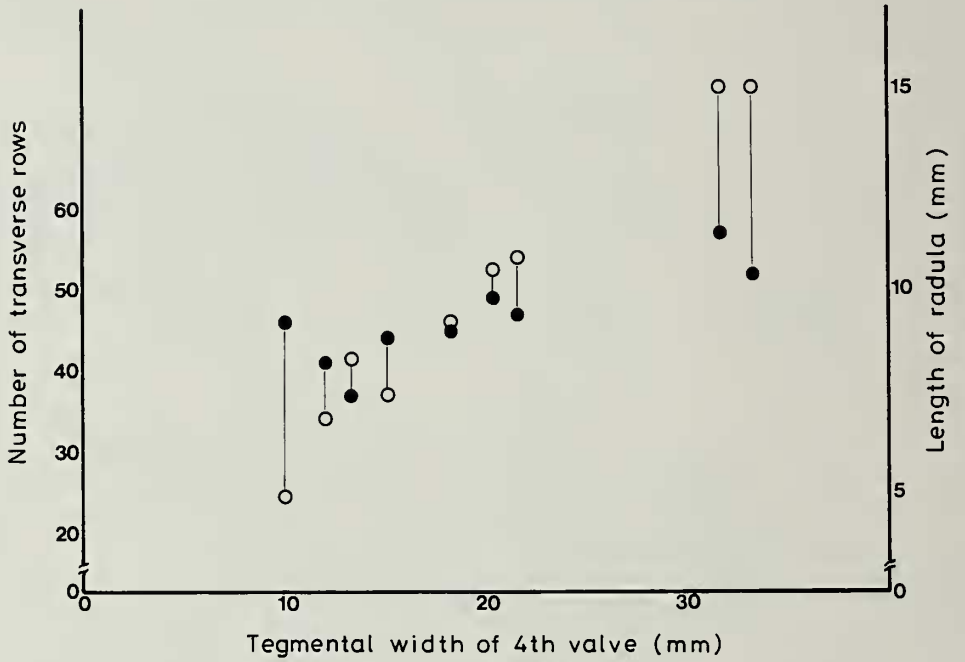


Figure 46

Relationship between width of valve IV and radula. Open circles, length; solid circles, number of transverse rows ($n$ = 9).

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## Explanation of Figures 47 to 52

Figure 47. *Placiphorella borealis* Pilsbry, 1893. Holotype (USNM 106922). Width of head valve 15 mm.

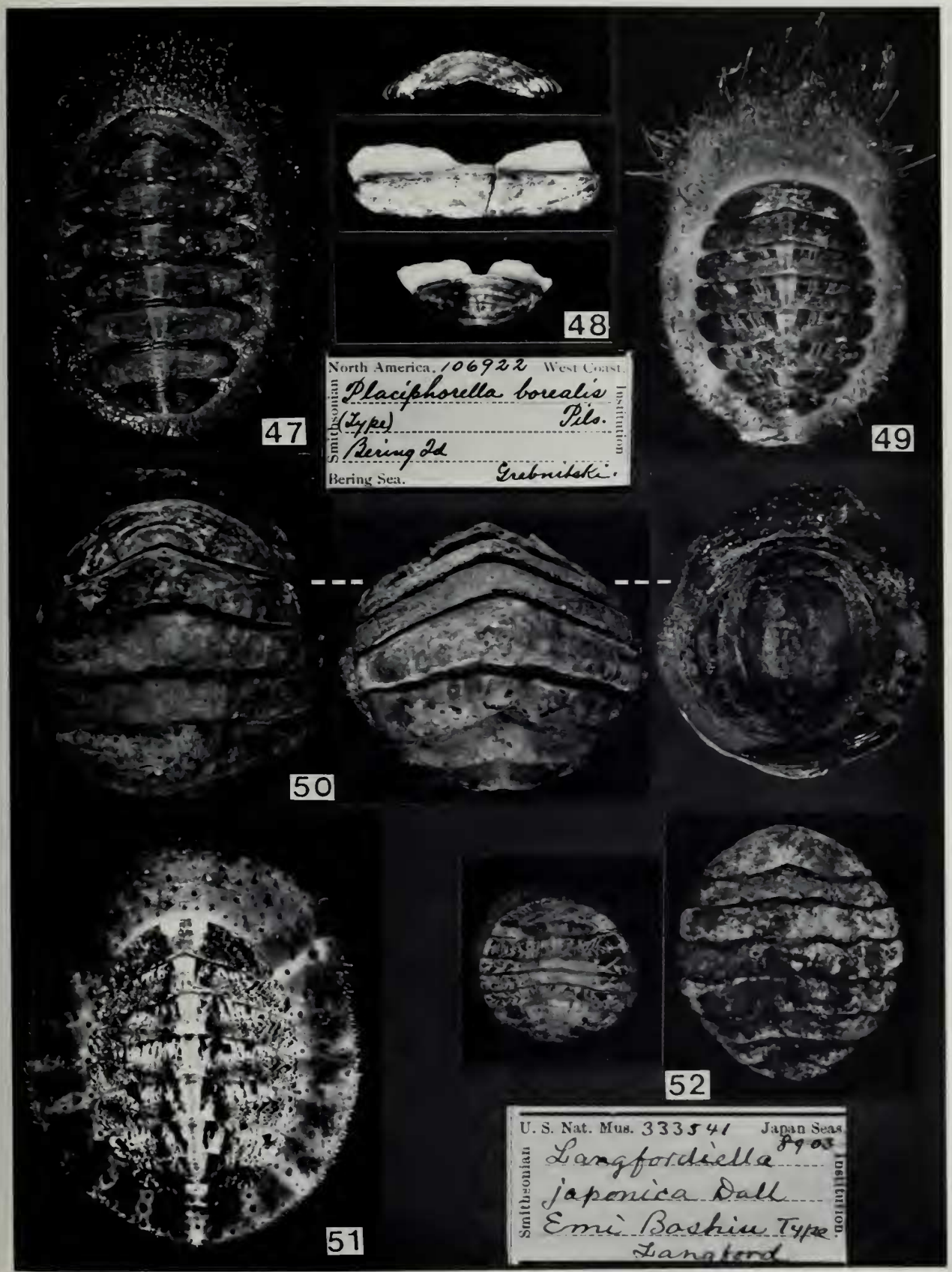
Figure 48. *Placiphorella borealis* Pilsbry, 1893. Approximate body length 45 mm (valve length 33.8 mm), from Nosappu, Hokkaido.

Figure 49. *Placiphorella* ***borealijaponica*** Saito & Okutani, sp. nov. Paratype 3.

Figure 50. *Chiton* (*Molpalia*) *stimpsoni* Gould, 1859. One of two syntypes (USNM 1646). Valve length 24.5 mm.

Figure 51. *Placiphorella stimpsoni* (Gould, 1859). Approximate body length 50 mm (valve length 33.4 mm), from Shimoda.

Figure 52. *Langfordiella japonica* Dall, 1925. Syntypes (USNM 333541). Valve length 35.0 mm and 20.3 mm respectively.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Smithsonian Institution
North America. 106922 West Coast.
Placiphorella borealis
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Smithsonian Institution
U. S. Nat. Mus. 333541 Japan Seas
Langfordiella
japonica Dall
Emi Boshin Type
Langford

in shape, thick, and platelike, and outer marginal large, thin, and platelike.

Digestive tract (Figure 44c): Stomach large, pouchlike, but appearing as double tube because of strong mesial constriction, light greenish brown; blind end of stomach extending dorsally to right side of dorsal surface of visceral mass; anterior intestine originating from left side of stomach, running posteriorly with U-shaped loop; intestinal valve directed inward; tract of posterior intestine simple, revolving one and a half times, ventrally leading back to rectum.

Heart: Anterior end of pericardium extending to the boundary between valves V and VI; heart with pair of auricular pores and pair of auriculo-ventricular ostia.

Gill: Holobranchial and abanal, number gradually increasing with growth (Figure 45); gonopore and nephridiopore situated between inside of two posteriormost gills and immediately behind posteriormost gill respectively.

Coloration: Preserved valves usually whitish, irregularly spotted or streaked with pink, brown, blue-green, and black; interior of valves uniformly white or tinted with blue-green; perinotum creamy yellow to light brown, with blackish bands; hyponotum uniformly creamy yellow to light brown, but anterior portion of both surfaces often maculated with red when alive.

Infraspecific and ontogenetic variations: Outline of valves generally slender in young individuals but roundish in adults. However, shape variable in adults; ratio of valve length to tegmentum width of valve IV ranging from 1.0 to 1.5; width sometimes wider than length (USNM 333541).

Head valve: Insertion plates already thickened in individual of 9.3 mm valve length, but pectination weak (Figure 33). In older animals, as pointed out by Taki (1954), insertion plate strongly pectinate (Figure 29) sometimes with accessory denticles anteriorly (Figure 30a).

Intermediate valves: Insertion plate of intermediate valves more pectinate with growth. Usually, in young individuals, sutural laminae barely connected to each other across jugal area (Figure 36), but well connected in full-grown adults (Figure 31). In adolescent or medium-sized individuals, sutural laminae sometimes separated by jugal sinus.

Tail valve: Allometric growth of tail valve remarkable (Taki, 1954).

Radula: Ratio of radula length to valve length almost constant from young individuals to full-grown adults and number of transverse rows gradually increases with growth (Figure 46).

Digestive tract: Blind end of stomach in young individuals (Figure 44a), situated in middle of right surface of visceral mass, intestinal valve runs anteriorly. As animal grows, blind end of stomach extends dorsally (Figure 44b), and turns dorsally to left side (Figure 44c), while intestinal valve turns inwardly.

**Remarks:** According to Johnson (1964), the holotype specimen of *Chiton stimpsoni* is USNM 1646. However, we found that two specimens are contained in the lot with this number. Both specimens are dried and intact animals, and they are decidedly conspecific. One that looks older than the other has written directly on hyponotum the number 1646; its valve length is 24.5 mm (Figure 50). The other specimen is accompanied by a paper label with the same number, and its valve length is 18.6 mm. In the original description, Gould said "length 1.5 poll." (=38.1 mm). Judging from the valve length, the larger one probably corresponds to Gould's specimen. Johnson (1964) thought the specimen that had been described and figured by Pilsbry (1893:308, pl. 63, figs. 85, 86, 88) was the holotype, although Pilsbry gave "length 17 mm" as the measurement of the "type of USNM 1646." Pilsbry's specimen may correspond to the smaller one, if Pilsbry's "length" means valve length. Furthermore, our observation of the specimens revealed no trace of disarticulation at the hands of Pilsbry, although he had described every character of the articulamenta of the valves. From the above-mentioned facts, it is not conclusive at present if either of these two specimens should be regarded as the holotype. Therefore, it is safe to treat them as the syntype in this paper.

*Placiphorella stimpsoni* has been long confused with *P. **borealijaponica*** sp. nov. (see **Remarks** under that species). *Placiphorella velata* (Carpenter MS) Dall, 1879, also closely resembles this species by its vivid coloration of the valves and girdle, and the exceedingly thick and pectinate insertion plate of the head valve. The two species are sufficiently separable by the shape of the tail valve, especially the posterior area, and the spicules of the bristles. Both species are distributed on both sides of the North Pacific and the southern distribution of each species extends to about 30°N. It is interesting that these two related forms are allopatrically distributed on both sides of the North Pacific.

Wu & Okutani (1985) recorded *Placiphorella "stimpsoni"* from a depth of 1210–1235 m off Mikura Island, Izu Islands, but re-examination of the specimen (NSMT Mo-60008) revealed that it is a quite different species, *Placiphorella* sp., which is closely related to the northeastern Pacific deep-water species *P. pacifica* Berry, 1919.

**Distribution:** Pacific coast of Japan, Japan Sea, and East China Sea, from southern part of Hokkaido to Kyushu. Found on littoral and sublittoral zones of rocky shores.

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